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PHYTOPHTHORA SP. ON *HEVEA BRASILIENSIS*

BY

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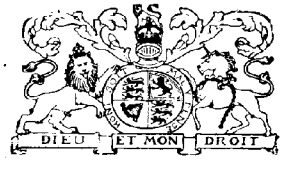
First Assistant to the Imperial Mycologist



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INTRODUCTION.

A POPULAR account of the disease of *Hevea* stem and fruit known in Burma as "Black Thread" and caused by a *Phytophthora* has been published by the Burma Department of Agriculture.[1] It is therefore not necessary in this paper to discuss the macroscopic characters of this disease.

The "Black Thread" disease first attracted the attention of the Burma Rubber Planters five or six years ago when the disease became very prominent by the damage it did on the tapping area. However it seems to be of a longer standing in Burma, at least on the fruits. As far back as 1905 specimens of diseased *Hevea* fruits from Mergui were sent to the Imperial Mycologist for examination, and in 1906 the Manager of the Rubber Plantation, Mergui, wrote that it was the fourth year the fruits in the garden had been attacked but that in no case had the disease been noticed on any other part of the tree except the fruit. They were at that time supposed to be attacked by a *Nectria*; but specimens of these diseased fruits sent in 1905 from Mergui have been examined by me and they show not only the presence of *Nectria* but also the resting conidia of a *Phytophthora* similar to those found by me in Burma in 1915. It is therefore reasonable to conclude that the disease of the fruits caused by a *Phytophthora* has been present in Burma at least since 1903; whether the disease on the tapping area is as old as this it is difficult to say.

MICROSCOPIC CHARACTERS.

Sections through diseased tapping areas show the cell walls turned brown or yellow and in some cases swollen and the cell contents destroyed. At times the stratification of the swollen cell wall appears very distinctly. The

[1] Dastur, J. F. Black Thread Disease of *Hevea* in Burma. Dept. Agr., Burma, Bull. No. 14, 1916.

cell cavity is sometimes filled with a yellow or brown gummy substance. On account of the death of the protoplasm and the loss of the water contents of the cell the cell walls collapse. The depression of the diseased area may be due to this collapse of the cell walls of the outer tissues. It is between these swollen and diseased cell walls that unseptate hyphæ are to be found.

It is difficult to trace the hyphæ, as they are generally completely masked by the presence of the brown pigment, which also prevents the affected cell walls from being stained by staining reagents. The presence of the hyphæ can be detected when the sections are treated with dilute ammonia or when they are subjected to ammonia vapour for a minute; chloral hydrate also tends to clear the pigment and thereby to reveal the presence of the fungus; boiling the sections for a few seconds in hydrochloric acid, as recommended by Ducomet,[1] either completely removes the pigment or leaves in the tissues only a slightly yellow tinge, if then washed in water and boiled with lactic acid, the hyphæ can be seen and will stain faintly blue with cotton blue. The hyphæ in the stem have been found to be intercellular and confined to the soft tissues. They are not to be found between the walls of the sclerotic cells though the latter are often filled with the brown gummy substance; they are also absent from between the walls of the wood cells. Haustoria are of rare occurrence and have been chiefly observed in the cortex; they are globose or finger-shaped (Fig. 1). In the tissues of the rind of the diseased fruits the mycelium is both inter-and intra-cellular. The hyphæ are confined to the tissues of the rind. They have not been found to penetrate the tissues of the woody shell, but in advanced cases of attack they reach the inside of the shell through the sutures. Bacteria and fungi like *Botryodiplodia*, *Fusarium*, *Nectria*, *Glœosporium* and others coming in the wake of *Phytophthora* then completely destroy the fruit.

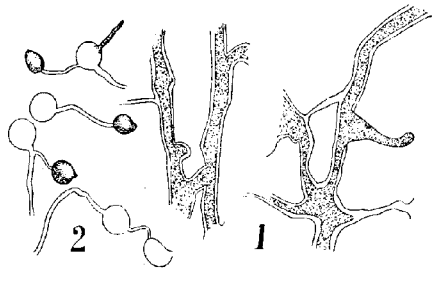

Fig. 1. Intercellular mycelium with haustoria from diseased tissues of the stem. ×365.
Fig. 2. Germination of the zoospores. ×480.

[1] Ducomet, V. Recherches sur le développement de quelques champignons parasites à thalle subcuticulaire, p. 11, 1907.

The hyphæ in the epidermal cells of the fruit form a stroma-like body which completely destroys the host cells (Figs. 1—3). When young this is composed of a single layer of pallisade cells with one or two rows of small basal cells. These cells enlarge and press against the cuticle pushing it out and ultimately rupturing it. The apical cells grow considerably in size, generally more breadthwise than lengthwise, thus losing their pallisade shape (Figs. 4 and 8); at the same time they also become sometimes lobed (Fig. 7). This stromatoid body has always been found to consist of loose cells. This is very clearly seen in tangential sections (Fig. 3). All the cells remain hyaline and are filled with finely granular protoplasm. From the top of the apical cells arise sporangiophores, usually one from each cell but, at times, as many as three (Figs. 2 and 4—8). The tissues of the fruit in the neighbourhood of the stroma-like body become discoloured and the cells are filled with some brown substance.

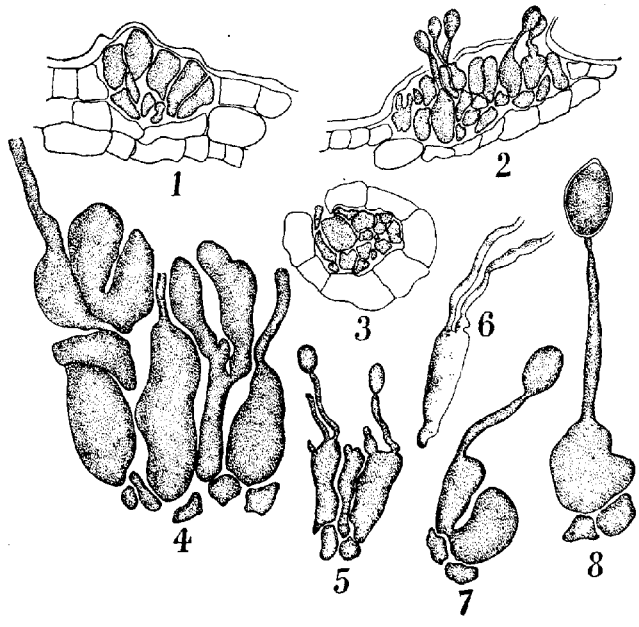

Fig. 1. A young stromatoid structure as seen in a transverse section of the diseased fruit. ×480.
Fig. 2. A mature structure bearing sporangia. ×215.
Fig. 3. A tangential section showing the loose cells forming the stroma-like body. ×480.
Figs. 4-8 Cells of the stromatoid body. ×480.

This formation of such a stroma-like body has not been, as yet, observed in any of the *Phytophthoras* known. The only other genus of the *Peronosporaceæ* in which something akin to it is formed is *Cystopus* and even here the base of the sorus consists merely of the swollen pedicels of the spore-chains and no formation of distinct basal cells interposed between the mycelium and the spore stalks occurs. De Bary considers that some characters found in *Pythium* suggest a common ancestry for *Cystopus* and *Phytophthora* and therefore the finding of this sorus-like structure in a *Phytophthora* is of interest as recalling the sori of the *Cystopus*. In *Cystopus*, however, the hyphæ beneath the epidermis bear directly a tuft of broad basidia from each of which a single chain of sporangia arises while in the *Phytophthora* under study the basidium or apical cell of the stromatoid body bears not alone one but as many as three sporangiophores.

The sporangiophores vary much in length; at times they are extremely small, the sporangia being almost sessile on the epidermis. Sometimes the spore stalk instead of bearing a sporangium directly after it has emerged from the epidermis continues its vegetative growth, and sends out branches which ultimately bear sporangia. The sporangiophores are simple; only occasionally branched. Sporangia are ovate or citron-shaped and terminal; at times lateral. The number of zoospores in a sporangium varies with the size of the sporangium. They are bean-shaped with a pointed anterior and have two cilia of unequal size. After swimming for some time the zoospores come to rest, lose their cilia, round off and germinate by sending out one to three germ-tubes which either continue their vegetative growth or when quite small swell at the tips to form secondary sporangia which when mature liberate one to three zoospores (Fig. 2, p. 218). Resting conidia are borne in the felt of mycelium on the surface of the fruit and on the tapping cut. They are honey-coloured, yellowish or at times hyaline, generally round, and they are either terminal, lateral, or intercalar.

Inoculations on *Hevea*.

In order to verify that this *Phytophthora* was the cause of the "Black Thread" disease, inoculation experiments with pure cultures obtained from diseased fruits have been carried out. The inoculations were at first done by putting a bit of the mycelium on a newly tapped surface; the inoculated areas were kept covered from 24 to 48 hours with cotton soaked in sterilized water. In four days the points inoculated showed signs of successful infection: they had turned either black or had vertical black lines, and had become slightly depressed. Within a week they showed typical symptoms of "Black

Thread." Vertical cracks were present on the inoculated areas and in some cases there was even an exudation of latex in drops. Sections from these areas showed the presence of intercellular hyphæ in the tissues, which had turned brown as in the case of naturally diseased tissues. Of the 55 inoculations made only 4 were unsuccessful.

Inoculations in a similar way were also made on renewing bark and old bark. Fifteen inoculations on the uninjured renewing bark where the cork formation had taken place and 18 inoculations on the uninjured old bark were made; all these failed. When, however, the bark was removed thereby exposing the outer green tissues of the cortex, the inoculations were successful. Of the 33 made only one failed. The inoculated tissues turned black, became depressed and developed vertical cracks. The blackening of the tissues did not extend beyond the cut and practically remained confined to the exposed green cortex, at least for three weeks, and had not during this period reached the cambium; only when the bark round the inoculated area was removed, laying bare healthy green tissues, did the infection spread outwards and attack the newly opened tissues. On branches also inoculations failed on the uninjured bark (7 inoculations were made) but succeeded on newly opened green tissues (18 inoculations were made). In those cases in which the tissues were wounded almost as far as the cambium, which was itself uninjured, gaping wounds exposing the wood were formed as the result of the inoculation. All these experiments were carried out on mature trees, *i.e.*, trees more than 6 to 7 years old. Trees 1 to 5 years old have also been experimented upon and the results have been the same. Six inoculations made on the uninjured thin epidermis have been unsuccessful, but on 19 young trees where the epidermis was injured the inoculations succeeded; the same results have been produced with saplings a few months old; in all these cases inoculations were made in the same way as described in the first case. In a few cases zoospores were used instead of the mycelium and inoculations on freshly opened tissues have been equally successful. Some of the successful inoculations have also produced sporangia.

Morphology of the Fungus in Culture Media.

This fungus has been grown in various culture media to induce it to produce oospores; but all attempts have failed.

In some agar media sporangia are much bigger than those found on the host plant. In nutrient media they vary from 25 to 51μ in length and 19 to 37μ in breadth; they are terminal, lateral or even intercalar. The number of zoospores liberated by some of these sporangia is as much as 30; the size of

the zoospores produced in culture media is almost the same as those produced on the host plant. The resting conidia in nutrient media do not show as much variation as the sporangia. They are only slightly bigger than those found in nature.

In water cultures the branching of sporangiophores is as complex as those of *Ph. omnivora ;* sporangia are of the same size as those found on the host plant.

The fungus grows luxuriantly in French bean juice agar, Quacker oat agar, Oat juice agar, Gram agar, and Green peas agar. In these media the aerial growth is very profuse, the culture tubes being completely filled by it within a week.

In glucose meat-extract agar the mycelium remains submerged and forms on the surface a thick undulating mat. The hyphæ are richly branched, irregularly swollen and full of highly granular protoplasm and oil globules. Sporangia and resting conidia are fairly numerous.

If this culture medium contains a trace of potassium phosphate the fungus remains sterile. Instead of this salt if one per cent. tannic acid be added the growth is similar but sporangia and resting conidia are produced in abundance. The colour of the resting conidia varies from deep honey to light yellow.

Klebs[1] and Kauffman[2] have found hæmoglobin to be one of the best substances for the formation of sexual organs in *Saprolegniaceæ*. In solutions of 0·1 per cent. and of 0·05 per cent. hæmoglobin and of 0·1 per cent. hæmoglobin with 0·1 per cent. of peptone and of 0·05 hæmoglobin with 0·02 per cent. peptone the *Phytophthora* under study did not produce these organs. The growth was rather poor. The mycelium remained settled at the bottom of the solution like a woolly ball. The mycelium was branched ; sporangia and resting conidia were fairly abundant.

As in liquid solutions the growth of the fungus is rather poor, 0·1 per cent. hæmoglobin was added at about 50°C. to sterilized French bean juice agar and Oat juice agar. The growth of the fungus was good. Sporangia and resting conidia were produced in large numbers. Resting conidia formed near a granule of hæmoglobin were generally deeply coloured, dark brown or deep honey-coloured ; no sexual spores were produced. Traces of potassium phosphate and calcium nitrate were added to French bean juice agar with

[1] Klebs, G. Zur Physiologie der Fortpflanzung einiger Pilze II *Saprolegnia mixta*. Jahrb. Wiss. Bot. xxxiii, 1899.

[2] Kauffman, C. H. A contribution to the Physiology of the *Saprolegniaceæ*, with special reference to the variations of sexual organs. Ann. Bot. xxii, 1908, p. 362.

hæmoglobin. The growth of the fungus was inclined to be confined to the surface of the medium. Hardly any sporangia were formed but resting conidia were produced in large numbers.

To glucose meat-extract agar were added traces of hæmoglobin, potassium phosphate, and calcium nitrate. The growth of the fungus in this medium was similar to that in glucose meat-extract agar. Hardly any sporangia and a few resting conidia were produced.

In horse dung agar the growth was very scanty and entirely submerged. Sporangia were produced in large numbers but resting conidia very few. In horse dung solution the growth was very poor. Sporangia were fairly many but resting conidia very few.

On sterilized potato cylinders the aerial growth is very little; at first the mycelium remains closely appressed to the surface of the cylinder. Resting conidia are produced in large numbers but sporangia very few.

On sterilized pods of green peas the fungus grows very well. There is a good aerial growth. Resting conidia are developed in large numbers; sporangia very few.

On sterilized ants the fungus did not grow.

In culture media this fungus does not produce the stroma-like bodies which it forms on fruits.

Comparison between the *Phytophthora* disease of *Hevea* in Burma and in other *Hevea*-growing countries.

In Ceylon *Hevea* canker was investigated in 1903 by Carruthers[1] and was supposed to be caused by a *Nectria*. Petch[2] in 1910 inoculated ten *Hevea* stems with *Phytophthora* spores obtained from diseased cacao fruits and three more by inserting in wounds pieces of diseased cacao pods. Six out of these thirteen inoculations gave definite infections and therefore he concluded that canker and pod disease of *Hevea* are caused by the same *Phytophthora* which is responsible for the stem canker and pod rot of cacao, *viz.*, *Ph. Faberi* Maub.

According to Petch[3] who has studied *Hevea* canker in Ceylon under field conditions in great detail, *Ph. Faberi*, the accepted cause of canker,

[1] Carruthers, J. B. Canker (*Nectria*) of Para Rubber (*Hevea Brasiliensis*). Circs. & Agr. Jour. Roy. Bot. Gard., Ceylon, II, No. 29, 1905, p. 445.

[2] Petch, T. Cacao and *Hevea* Canker. Circs. & Agr. Jour. Roy. Bot. Gard., Ceylon, V, No. 13, 1910, p. 159.

[3] Petch, T. The Physiology and Disease of *Hevea Brasiliensis*, 1911, pp. 199—201.

does not cause a true canker on *Hevea;* the diseased bark is usually smooth and outwardly appears to be sound; the fungus forms no open wounds and therefore he considers the popular name canker to be a misnomer. Again a cankered tree may be killed and the bark destroyed "without the occurrence of any roughness or open wounds." "Black Thread" causes a true canker; the diseased renewing bark in advanced cases completely decays and falls off leaving a big gaping wound and in the case of a minor attack the renewal of the bark is rough with vertical swollen ridges of wound tissue. However serious be the attack of "Black Thread," it has not been known to kill the tree. *Hevea* canker is found even when the stem has acquired a thick outer brown bark while "Black Thread" is confined on the stem solely to the tapping surface. In the case of *Hevea* canker, therefore, there is generally no outward indication of the disease while the presence of the Burma disease can always be spotted immediately on its appearance. In some cases, however, the cankered bark exudes a reddish or purplish liquid, which gives an outward symptom of the diseased condition of the bark: in the Burma disease no such discoloured exudation has been observed, but there is an exudation of white latex from the vertical cracks on the diseased parts. From Petch's accounts *Hevea* canker does not appear to be a wound parasite on the stem, but "Black Thread" is, as is shown by inoculation experiments and by the characters of this disease in nature.

During the prolonged rains of 1909 and 1910 Petch[1] found in Ceylon the decay of the renewing bark on the tapped surfaces. The decay was first indicated by the appearance of vertical black lines, just above the tapping cut. This decay was found to extend to the wood; the bark on the diseased area rotted and left long narrow wounds extending to the wood. The progress of the decay stopped when the rains ceased and the wounds healed up but the renewal of the bark was rough with vertical swollen ridges of wound tissue. This description by Petch of the disease of the tapping surface in Ceylon very much resembles that of "Black Thread" of Burma; but there is one point of minor difference; according to Petch in some cases the decay travelled downwards and involved the untapped bark; Rutgers[2] also has found in Java that the disease penetrates downward in the old bark; in Burma, however, "Black Thread" has never been observed to involve the untapped bark. Petch considers the decay of the renewing bark on the tapped surface due

[1] Petch, T. Cacao and *Hevea* Canker. Circs. & Agr. Jour. Roy. Bot. Gard., Ceylon, V, No. 13, 1910, p. 166.

[2] Rutgers, A. A. L. and Arens, P. Diseases of *Hevea Brasiliensis* in Java. Internationaal Rubber-Congres met Tentoonstelling, Batavia, 1914, p. 5.

to an excess of moisture on the layer exposed to the rain during tapping and not due to any pathogenic cause, because he failed to reproduce this decay by means of organisms found in the decayed bark. He does not enumerate them but presumably he did not find a *Phytophthora* among them. The writer found in Burma that the decaying bark was soon overrun by saprophytic fungi like *Fusarium*, *Cephalosporium* and *Spicaria*, especially the first. To see if any of them was able to cause " Black Thread " tapped areas were inoculated with pure cultures of these fungi but in all cases negative results were obtained. The sporangia of *Phytophthora* are very rarely formed on the diseased stem in Burma, and the writer succeeded in getting the sporangia from the incubated decayed bark only in a few cases after many attempts and that, too, when a thick piece from the diseased part of the stem was incubated after washing the piece in corrosive sublimate. Even then a pure growth of the fungus was not obtained as there was also a Fusarial growth.

Petch's[1] account of *Hevea* pods attacked by *Phytophthora* in Ceylon may well apply to the diseased pods in Burma, but in Ceylon the fungus from the fruit may grow through the stalk into the branch and kill it for some distance, while in Burma the disease from the fruit has not been found to travel on to the stalk and thence to the branch, though diseased fruits have been found hanging on the trees for several weeks. In the case of a fruit badly attacked by *Phytophthora* in Burma, the woody shell underneath the diseased soft rind shows black discoloured areas. On sectioning these, *Botryodiplodia* hyphæ have been found in the tissues. This fungus from the woody shell has been found to travel on to the thalamus; and from there it may reach the fruit stalk and eventually kill it. Petch[2] has shown that *Botryodiplodia Theobromeæ* Pat. may follow an attack of *Glœosporium* on *Hevea* branches; similarly it is possible that on the fruit in Burma *Botryodiplodia* follows an attack of *Phytophthora* and then spreads to the fruit stalk. It seems probable, therefore, that in Ceylon also the death of the fruit stalk may be due to *Botryodiplodia* and not due to *Phytophthora* as supposed by Petch, especially since he says that *Phytophthora* has not been isolated from diseased fruit-bearing shoots.

In Ceylon *Ph. Faberi* has been found to attack the collar and the roots as well, in fact all parts of the tree, except leaves. But McRae and Sundararaman,[3] who have studied in Travancore and Cochin a disease of *Hevea* which they consider to be due to *Ph. Faberi*, have found the presence of this fungus

[1] Petch, T. *loc. cit.*

[2] Petch, T. Physiology and Diseases of *Hevea Brasiliensis*, 1911, p. 220.

[3] McRae, W. and Sundararaman, S. Leaf-fall of *Hevea*. The Planters' Chronicle, X, No. 37, 1915, p. 452.

not only on fruits and the tapping area of the stem but also on young tender leaflets, leaves in the buds, stalk of leaflets, main stalk of the leaf and on young branches. In Burma the parasite has been found to attack only fruits and the tapping surface. McRae and Sundararaman report that a second leaf-fall occurs in Travancore and Cochin in July and August, and they are of opinion that though their experiments do not prove that *Ph. Faberi* is the cause of the second leaf-fall, the presence of this fungus on the leaves is suggestive. According to Petch[1] the fungus from the fruits passes on to the green shoots and kills them back or it attacks the stalks and causes extensive defoliation and in a recent Report[2] of the Department of Agriculture, Ceylon, he says that the leaf-fall which often follows the fruit disease and is characterized by the appearance of a dark brown ring on the leaf stalk is caused by *Ph. Faberi*. A similar leaf-fall also occurs at Twante in Burma but the writer could not trace the fall to any pathogenic fungus. The falling leaf stalks were found to be healthy as far as any parasitic organism was concerned and the leaf stalk did not show any dark brown ring. The falling leaves did not become curled or flaccid. The writer was inclined to attribute the fall to the excessive humidity prevalent in July.

In Cochin and Travancore the *Phytophthora* which attacks fruits of *Hevea* producing symptoms similar to those found on diseased fruits in Burma also causes the darkening of the renewing bark a little above the tapping cut; it seems, therefore, that in all probability this *Phytophthora*, which McRae[3] does not now consider to be the same as *Ph. Faberi*, is identical with the one causing "Black Thread" in Burma, in spite of the differences enumerated above. The tendency of the South India *Phytophthora* to attack various parts of *Hevea* is probably to be attributed to local climatic conditions.

Rutgers[4] distinguishes two acute forms of *Hevea* canker in Java, Sumatra and Borneo which he considers to be due to the same fungus *Ph. Faberi*. One form is form A or "Streepjeskanker" and the other is form B or "Vlekkanker." His illustration and description of the former, "Streepjeskanker," clearly show

1 Petch, T. The Fungus-diseases of *Hevea brasiliensis*. Internationaal Rubber-Congres met Tentoonstelling, Batavia, 1914, p. 12.

2 Petch, T. Rep. Dept. Agr. Ceylon, July 1912 to Dec. 1913. Pub. in 1914, p. c7.

3 McRae, W. Administration Report of the Government Mycologist for 1915-1916, Rep. Dept. Agr., Madras, 1915-1916, Pub. 1916, p. 53.

4 Rutgers, A. A. L. and Dammerman, K. W. Ziekten en Beschadigingen van *Hevea Brasiliensis* op Java. Dep. Landbouw Nijverheid en Handel. Meded. Labor. voor Plantenziekten. No. 10, 1914, pp. 27—30, and

Rutgers, A. A. L. and Arens, P. *loc. cit.* 1914, pp. 27—30.

that it is identical with the " Black Thread " disease of *Hevea* in Burma. The form B, " Vlekkanker " includes the well-known greyish-brown or purplish-red or red patches in the bark first described in the canker formed on cacao and subsequently in the rubber canker described by Petch in Ceylon. Besides the red canker patches of form B, the innermost layers of the bark quite near the cambium, or the cambium itself, show a slight discolouration, which appears on the tapping cuts in the form of dirty brown or greyish points and lines or as a dirty brown line in the place of the cambium. This form C gives rise to burrs if not treated in time. It is not clear why Rutgers considers the two acute forms, A and B noted above to be due to the same fungus *Ph. Faberi*. He inoculated cacao *Phytophthora* on *Hevea* and got the typical canker, form B, in every case; but when he inoculated *Hevea* with *Phytophthora* from *Hevea* he got the typical black vertical stripes of form A or " Streepjeskanker." Sporangia were presumably obtained from the diseased dark stripes on the tapping cut where they are found in abundance in Java. It is unfortunate that *Hevea Phytophthora* has not been inoculated on cacao, either by Petch or by Rutgers.

According to Rutgers[1] microscopic examination of sections of *Hevea* tissues attacked by canker shows the formation of secondary cambium outside the primary cambium round the brown dead cells. Mr. Bryce, Acting Botanist and Mycologist to the Government of Ceylon, kindly sent me spirit specimens of cankered *Hevea* bark from Ceylon. Sections from this bark showed the formation of secondary cambium surrounding the dead cells as observed by Rutgers in Java, while sections from renewing bark attacked by " Black Thread " in Burma do not show any formation of secondary cambium. These specimens of cankered bark from Ceylon also clearly showed the microscopic differences between canker and " Black Thread." Mr. Bryce also sent me specimens of diseased renewing bark from Ceylon. Not only in their external characters these specimens were identical with those of " Black Thread " disease of Burma, but microscopical examination also showed them to be identical. At the same time specimens of " Black Thread " on *Hevea* from Burma were sent to the Government Mycologist, Ceylon, with the request to let me know if a similar disease was known in Ceylon. Mr. Bryce took the trouble of examining these specimens and wrote to me that he had no hesitation in pronouncing the " Black Thread " disease of Burma to be the same as the one occurring on the tapping area in Ceylon where the disease is known variously

[1] Rutgers, A. A. L. *Hevea*-Canker. Dep. Landbouw Nijverheid en Handel, Meded. Afdeeling voor Plantenziekten, No. 2, 1912, p. 5.

as " Bark Rot," " Decay of renewing bark," and sometimes as " Dieback," and this " Bark Rot," according to him, is capable of explanation on purely physiological grounds.[1]

From the above account it is clear that on *Hevea* there are two distinct forms of disease caused by *Phytophthora*, one causes canker in Ceylon, Borneo, Java and Sumatra, identical with the cacao canker ; and it is significant that this *Hevea* canker does not cause much damage on plantations of *Hevea* only, but is decidedly more serious on mixed *Hevea* and cacao plantations. The other form causes black stripes on the tapping area. This is found in Borneo, Java and Sumatra, along with the former disease ; and in Burma, Cochin and Travancore by itself. Furthermore, the decay of renewing bark, first recorded by Petch[2] in Ceylon, is due to the second form and not due to wet condition as supposed by him.

It seems clear that we have on *Hevea* two different species of *Phytophthora* causing two distinct kinds of diseases instead of one fungus causing two distinct symptoms of one disease. Of these two different species one is *Ph. Faberi* which causes *Hevea* canker identical with that of cacao as shown by the inoculation experiments of Petch and Rutgers ; and the other species causes " Streepjeskanker " or " Black Thread " disease as seen from the inoculation experiments made by Rutgers in Java and by me in Burma.

This veiw of there being two diseases of *Hevea* stem caused by two species of *Phytophthora* is strengthened by inoculation experiments and by morphological study.

Fruits and cuttings of *Theobroma Cacao*, kindly furnished by Mr. C. D. Mahaluxmiwala, Superintendent, Municipal Gardens, Bombay, and by Mr. H. E. Houghton, Superintendent, Agri-Horticultural Gardens, Madras, were inoculated with pure cultures of *Phytophthora* taken from *Hevea* fruits in Burma. Four cacao fruits, one about one and a half inch long and the other three about four to five inches long, were inoculated either with zoospores or with vigorously growing mycelium from pure cultures. Two were inoculated through cuts made on the surface and the other two were inoculated on the unwounded surface. Though these fruits were kept in moist chambers for over a fortnight, there was absolutely no trace of the inoculation succeeding. Four

[1] Bryce, G. Report of the Acting Botanist and Mycologist. Trop. Agr., XLVII, No. 1, 1916, p. 29.

[2] Petch, T. Cacao and *Hevea* Canker. Circs. & Agri. Jour. Roy. Bot. Gard., Ceylon, V, No. 13, 1910, p. 160.

cuttings of cacao, the thickest as thick as a man's thumb, were also inoculated in a similar way as the fruits. These cuttings were stood in flower vases filled with water and they were then kept in moist chambers but the inoculations here also failed. Petch[1] having recorded *Artocarpus incisa* as being one of the hosts of *Ph. Faberi*, fruits and cuttings of this plant and of *Artocarpus integrifolia* were inoculated in the same way as those of *Theobroma Cacao*; they also gave the same negative results.

Coleman[2] has shown that very young seedlings of *Solanum melongena* and *Lycopersicum esculentum* between one and three inches high possessing two or three leaves can be successfully inoculated with *Ph. Faberi* from cacao fruits; seedlings of these plants which had not dropped their cotyledonous leaves were inoculated with vigorously growing mycelium from pure cultures. In every case the inoculation failed. Very small plants of potatoes also failed to take the inoculation. But successful infections were secured on seedlings of *Gilia* spp., *Clarkia* spp., *Salpiglossis* spp., and *Ricinus communis*. The former three garden plants have been known to serve as hosts for *Ph. omnivora* and *Ph. parasitica*, and *Clarkia* and *Salpiglossis* also for *Ph. Arecæ* and *Ph. Faberi*.

In the Philippines, Mendiola and Espino[3] have recently found a disease of fruits of *Carica papaya* caused by *Ph. Faberi*, and this fungus from cacao they have succeeded in inoculating on papaya fruits; but these fruits did not give successful infections when inoculated with the *Phytophthora* under study.

The conidiophores on the fruit in Burma burst through the epidermis in clusters, they are simple or occasionally branched, and extremely short or up to 102μ long. They at times are so small that the sporangia appear almost sessile on the epidermis. Petch does not give his measurements of *Ph. Faberi* on *Hevea* but quotes those given by von Faber[4] who has studied this disease on cacao and according to whom the sporangiophores measure 150—200μ. Sporangia of the Burma fungus are generally pear-shaped and not very variable in shape; on fruits and stems they measure 20·7—35·7 × 15·0—25·5μ. In rare cases the extreme length was 44·2μ and breadth 29·0μ. The

[1] Petch, T. Ceylon Administration Report, 1906, Roy. Bot. Gardens.

[2] Coleman, L. C. Diseases of the Areca Palm, I, Koleroga. Mycol. Ser. Bull. No. II, Dept. Agri., Mysore State, 1910, p. 80.

[3] Mendiola, N. and Espino, R. B. Some Phycomycetous Diseases of Cultivated Plants in the Philippines. The Philippine Agriculturist and Forester, V, No. 3, 1916, p. 67.

[4] Von Faber, F. C. Die *Phytophthora*—Fäule der Kakaofrüchte. Arb. Kais. Biol. Anst. Land-und Forstwirtschaft, VII, 1910, p. 200.

average of 50 measurements gives the length as 28·5μ and breadth as 20·4μ; the proportion of breadth to length being 100 : 140. Thus they are smaller than those of *Ph. Faberi* which measure 42—80 × 25—30μ according to von Faber. The zoospores of the Burma species measure 7·5—12·5 × 5·0—7·5μ (those of *Faberi* are not given), and the number of zoospores emitted from a single sporangium got from the fruits varies from 3—10 whereas von Faber has observed as many as 20 zoospores arising from a single sporangium. According to Rorer[1] sporangia of *Ph. Faberi* from cacao measure 30—60 × 21—30μ, usually 30—50 × 25—27μ and emit from 15—30 zoospores. What von Faber and Coleman call oospores are really resting conidia or chlamydospores similar to those found in *Ph. parasitica*, *Ph. Colocasiæ*, and *Ph. infestans*. They measure 22—45μ according to these authors and according to Rorer 30—50μ. Those of the Burma fungus are much smaller and measure 17—34μ in diameter.

Peters[2] has described a disease of *Hevea* fruits in the Cameroons caused by a *Phytophthora* but he considers its identity with *Ph. Faberi* to be doubtful. From his scanty account of the disease it is not possible to say with certainty whether it is similar to the one found on *Hevea* fruits in Burma. But judging from the measurement given by him it seems probable that the fruit disease in the Cameroons is allied to that found in Burma. The sporangia on the diseased fruits in Burma are slightly smaller than those on the diseased fruits in the Cameroons, where the proportion of breadth to length is 100 : 144, but those produced in pure cultures are similar in both the cases. Similarly the resting spore (called by Peters oospores) are bigger on the fruits in the Cameroons than those found in Burma but those produced in pure cultures are of the same size.

Remedial Measures.

In a previous paper[3] preventive measures to check the disease have been suggested, *viz.*, thinning out thickly planted areas, systematic removal of diseased fruits and stopping of tapping on trees attacked by "Black Thread." In Java, Rutgers[4] recommends the treating of the affected bark with a solution of 20% carbolineum plantarium every 5 days and of removing from

[1] Rorer, J. B. Pod-Rot, Canker and Chupon-Wilt of Cacao caused by *Phytophthora* sp. Bull. of Trinidad Dept., Agri., IX, No. 65, 1910, p. 91.

[2] Peters. Uber eine Fruchtfäule von *Herea brasiliensis* in Kamerun. Ber. üb. d. Tätigkeit d. Kais. Biol. Anst. im Jahre 1911. Mitt. Kais. Biol. Anst. 1912, No. 12.

[3] Dastur, J. F. *loc. cit.*

[4] Rutgers, A. A. L. and Arens, P. *loc. cit.*, p. 9, and
Rutgers, A. A. L. and Dammerman, K. W. *loc. cit.*, p. 31.

the tapping round trees affected with " Streepjeskanker." According to McRae and Sundararaman[1] in Mundakayam (Travancore) the rot of renewing bark can be checked by putting with the thumb a thin smear of a mixture of tar and tallow over the affected portion. When this paper was in the press the author's Bulletin was reviewed in the Planters' Chronicle[2] in which it is stated that the " Black Thread " disease is exactly similar to " Bark Rot " of *Hevea* in South India and that it has been found that a combination of cessation of tapping on attacked trees with the application of a thin smear of a mixture of tar and tallow to the diseased spot has proved very effective. The mixture is applied with the finger and then rubbed with a small piece of gunny so as to get only a smear confined to the bark area attacked and its action appears to be two-fold. The tar acts as an antiseptic while the tallow forms a waterproof covering and thus deprives the fungus of the moisture so necessary for its growth and welfare. After the monsoon the treated areas gradually shed a thin scale of tar coated bark and expose a clean healthy surface beneath. Mr. Anstead, Deputy Director of Agriculture, Planting Districts, Madras, has very kindly called my attention to the following extract from the Minutes of a Meeting of the Ceylon Committee of Agriculture. " The Acting Government Mycologist has instituted a series of experiments with a view to prevent further development of the bark rot disease of *Hevea* rubber. All other trees under tapping experiments have had the newly tapped surface covered with a thin coating of a mixture made by boiling one ounce of sulphur in half a kerosine tin of water and adding equal parts of fresh cowdung and clay till a thick paste is obtained. A pinch of salt added will tend to keep the paste moist and prevent cracking and peeling off the trees. The object is to protect the exposed delicate cambium layer from sun and drying winds, as a precaution against bark rot and to encourage good bark renewal. This should be applied monthly during dry weather within a quarter of an inch of the tapping area."

With regard to this last method it is difficult to see how this monthly application within a quarter of an inch of the tapping cut will completely prevent bark rot or " Black Thread " as the infection generally begins just on the newly opened cut and very possibly the renewal of the bark on this cut will have commenced before it gets covered with the mixture and then the chances of its getting infected are considerably reduced. In South India this mixture has also proved beneficial but it is applied all over the tapped

[1] McRae, W. and Sundararaman, S. *loc. cit.*

[2] Anonymous. Bark Rot of *Hevea*. The Planters' Chronicle, XI, No. 31, 1916, p. 272.

area, when tapping ceases, as it does in some districts, on account of the dry weather; the bark renews quickly and well beneath this covering and the bark rot is reduced.

In those parts of Burma where the rainfall is not as heavy as in South India the writer found that merely not tapping diseased trees during the rains checked the progress of the disease, and therefore it seemed there was no necessity to apply any mixture which would control the disease, except perhaps in extremely wet districts, such as Mergui, where the application of a thin mixture of tar and tallow smeared over the diseased area in the manner described above should be effective. Covering the tapped surface with a mixture of clay, cowdung and sulphur as is done in South India may be tried.

PUSA,
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